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Hydrological Modeling and Impact of Climate Change: (Historical Overview on Northern Areas of Pakistan)

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Abstract: ***Climate change is caused due to emission of greenhouse gases, which results in an increase the global mean atmospheric temperature. Pakistan is a bit contributor towards the greenhouse gases but it is most affected due to impacts of climatic change. The northern areas of Pakistan have complex climate change. In this research paper historical, current and future climate change was assessed and compared. Historical trend of climatic change shows tremendous rise in temperature and precipitation in northern areas of Pakistan. Current scenario indicates decreasing trend in glaciers melting, which results a decrease in stream flow, it indicates a relation between melt rates increase and decrease glacier volumes. Regional Climate Models shows regular warming until the end of the 21st century. Future projections of climatic change indicates rise in summer precipitation and no momentous increase in mean precipitation of winter season.***
Keywords: Climate change, RCMs, GCMs, Hydrological modeling, Greenhouse gases

I. INTRODUCTION

Changing of climate is anticipated to create adverse impacts on Pakistan. Melting of glaciers increased in the Himalayas due to increase of extreme weather conditions such as heat and drought conditions, which predict rise in rate of flow in volume of many important rivers of Pakistan. The trend of changing climate is anticipated to continue as Pakistan climate is rapidly varied over the past several decades. Pakistan contributing less than 1% towards the Green House gases (GHG) [1] but it is mostly affected country due to climatic change, and it has less resources to adopt to its bad effects [2]. Population migration in larger numbers as well as food and water security are already in risk. The changing of climate has large impacts on the lives of people.

The temperature of the earth air has observed to increase by 0.85 Celsius for 1881–2012 and for every of the last three decades, described by the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC, AR5). Increase in temperature has been noted for every succeeded decade. It has been observed that under low emission scenario RCP2.6, the mean projected temperature increase over one Celsius and under high emission scenario, it is increased by four Celsius [3]. In many research studies, increasing trend of temperature was observed in the Himalayan basin [4, 5, 6]. Immerzeel et al. conducted a study in the catchment of Himalayas and results revealed that due to rise in glacier melt and increase in rainfall water availability may not decrease in 21st century [7].

II. HISTORICAL BACKGROUND

The northern areas of Pakistan has a complex climate especially of Upper Indus basin. In many research studies, a historical trends in precipitation and temperature in the Upper Indus basin has been investigated. Trend analysis of precipitation in Northern areas of Pakistan from 1961 to 1990 for 17 stations shows huge rise in annual, winter and summer precipitation [8].The trend of air temperature from 1961 to 2000 were analyzed and it showed that (i) in every season diurnal temperature range is increased constantly, (ii) Winter maximum and mean temperature show notable rise and (iii) Consistent declining trend were observed in mean and minimum summer temperatures [9]. For the same stations for recent period (1980–2009), same results were found [10]. Baltoro region dataset trend analysis in the Karakoram from 1958 to 1990 showed negative trend for summer temperature and from 1991 to 2001showed a positive trend [11]. From 1970 to 1990 a trend of rise in annual precipitation were found and at 1990s decreasing trend were experienced. These findings were not confirmed by analysis on different gridded precipitation products trends [12]. The winter precipitation main source is winter westerly disturbances, and these studies show powerful intra-seasonal changes and enhanced frequency trend and strength of these disturbances in the Karakoram and western Himalaya from 1979 and 2010 Karakuram and western Himalaya disturbances strength, leading to raise heavy precipitation in winter [13].

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III. PRESENT SCENARIO

During the last decade, there is many discussion on the climatic change impacts on glaciers in the northern areas of Pakistan. As compared to other regions of the world which is mountainous, Himalayan range show similar trend of decreasing mass, Pamir and Karakuram mountain regions glaciers show balance on neutral mass on mean and consist of large number of flow producing glaciers [14]. Inconsistency of Karakuram has not been described, but a feasible cause could be a union of increase in precipitation and decrease in summer temperatures. Further studies and understanding are required processes of atmospheric directing to peak-altitude precipitation. Snow cover analysis on MODIS based it was found that trend of snow cover was increased in Hunza basin which support the previous hypothesis [15]. Snow cover decreasing trend was found in sub basin which are westerly influenced including Hunza and snow cover increasing trend was found in sub basin which are monsoon influenced[16]. Sutlej basin is dominated by snow cover of monsoon, which show snow cover decrease from 2000 to 2009 [17]. From many studies, it is concluded that there is no reduction occur in yearly snowfall in Karakoram under warming climate, because non-monsoonal winter dominated seasonal cycle.

Glacier melting dependent upon rising in temperature, which in near future results in large stream flow and show decrease in distant future. The increase melt rates of glaciers results in less volume of glaciers which conclude the total amount of glacier melts. It is highly variable when the melting trend of glaciers changes from positive to negative. Tarbela reservoir inflow show a decreasing trend which is the main reservoir on Indus river. Declining or stable trends in runoff at various locations are identified on analysis of upstream stream flow trend [18]. From previous studies it is indicated that accelerated melt in the great segment of the Upper Indus Basin are not yet observed which can be attribute to the Karkoram. But in recent study on Shigar river basin report increasing flow [19]. However, these are not related to the alive of the Karakoram anomaly. With increase of temperature and precipitation rise in flow is possible under conditions of neutral glacier mass balance.

IV. FUTURE OUTLOOK

For generation future climatic change projections in the northern areas of Pakistan, climatic simulations used. Precipitation change analysis shows large number of General Circulation Models runs indicate by precipitation change analysis shows that rise in precipitation of summer and on average no important changes in winter precipitation. Precipitation change spread is large from the GCM covering and it is difficult to simulate the complex climate of northern areas of Pakistan. Upper Indus has greater warming than the lower Indus and analysis shows constant warming at the end of century. By using Regional Climate models shows regular increase in warming at end of century, Upper Indus is more warmer than lower Indus. There is a non-uniform change in precipitation projections decreases projection in the lower parts and with increases projected for the upper parts [20]. In impact studies, RCMs direct use of RCMs caring needs to be taken. The RCMs show large uncertainties in both precipitation and temperature after analyzing the uncertainty of the CORDEX South Asia Regional Climatic Models that shows a larger cold bias and are unable to simulate experienced warming trends. Under such complex conditions, empirical-statistical downscaling is best suited and is an additional technique to produce forcing for impact climatic change models, with transfer functions climatic model results is statistically right with local experiences in case of a historical period [21]. By stochastic weather generator for RCM in northern areas lead to project increase in precipitation and rise in intensity in wettest months and year round uniformly increase temperature [22].

V. DISCUSSION

Distributed hydrological model is used with best suit of climatic models and with advanced technique of statistical downscaling. Availability of water seasonally shifts for first time in northern areas of Pakistan are analyzed with variations in hydrological extremes. Due to future climate historical uncertainties, it is difficult to analyze the future hydrological changes in the Upper Indus basin of Pakistan and due to uncertainties in glacier melt, hydrological model processing and parameters.

In this study, it is concluded that northern areas have uncertain future in water availability. At the end of 21st century, projection in water changes ranges from -15% to 60% with respect to 1971-2000. It is very important to take analysis, which counter the future uncertainty so on the basis of ensemble of climate models hydrological projections to be model, which represent all possible futures.

Water availability trend in intra-annual shifts and basin-wide patterns are constant across climatic change scenarios, regardless of many water and future climatic uncertainties. Less increase in summer flows were observed in near future from 2021 to 2050 and combination of rise flows in other season and for far future from 2071 to 2100 increase in summer flows with combination flows of other season. Under different models and scenarios rise in frequency and intensity of peak discharges were found in northern areas of Pakistan and indirect rise in events of flooding during the 21st century.

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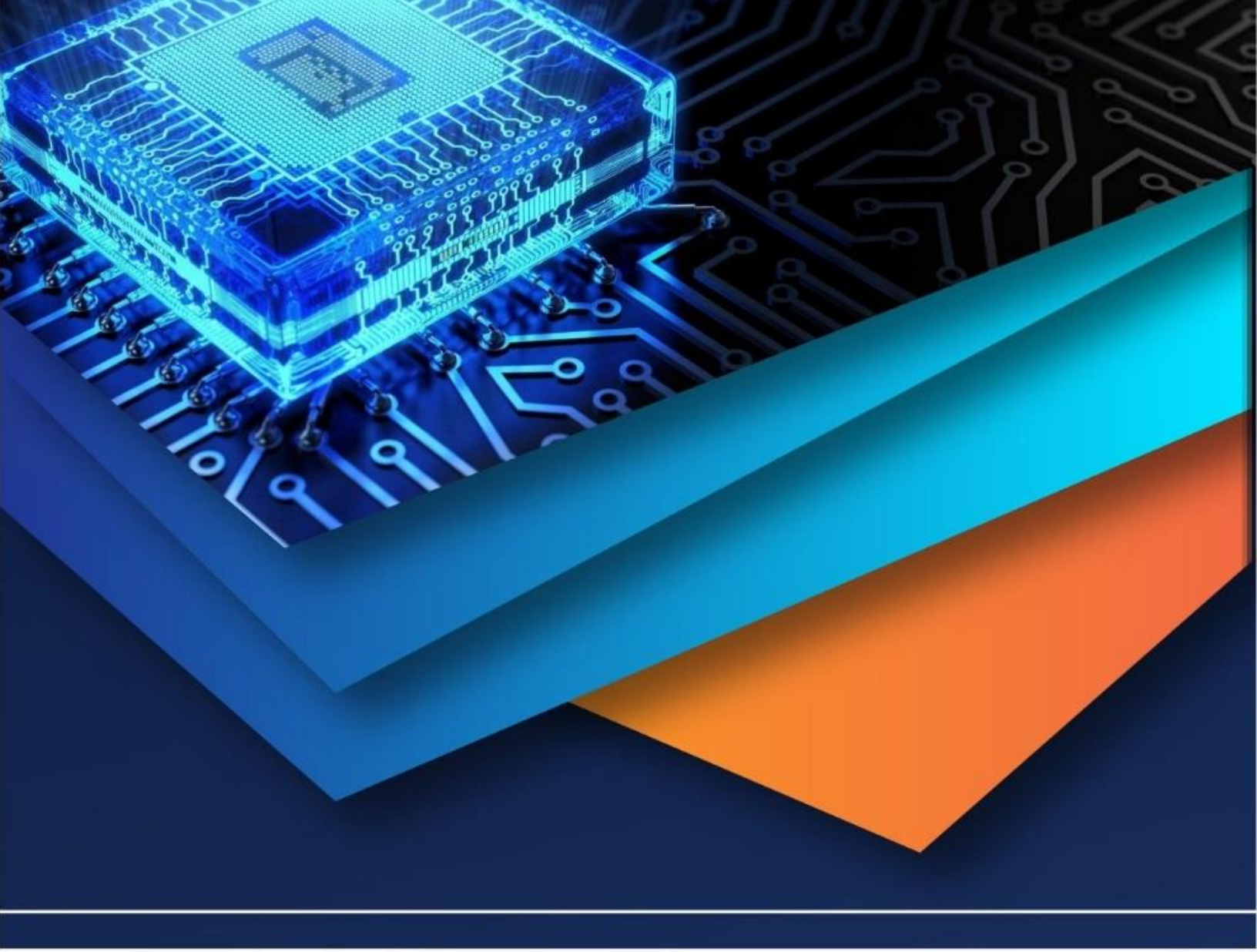

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